

THE SPACE EXPLORATION TEAM INQUIRY MODEL: LINKING NASA TO URBAN EDUCATION INITIATIVES

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Linking NASA Education Efforts

This paper describes how two different National Aeronautics and Space Administration (NASA) programs, one funded by the Office of Space Science (Code S), the other by the Office of Equal Opportunity (Code EU), teamed up with an outstanding high school science teacher to produce effective strategies to teach space science to inner city Latino high school students. The innovation arose out of a dialogue between a Jet Propulsion Laboratory (JPL) Science Educator, Richard Shope, and a National Board Certified High School Science Teacher, Dr. Lloyd Chapman at Garfield High School in East Los Angeles, about how space science proceeds at NASA/JPL and how students learn about space science in the classroom.

As a member of a flight project team at JPL, Shope has observed and participated in science and technology inquiry in NASA efforts to explore space. Chapman has intimate knowledge of the day-to-day challenges within the high school learning environment. Working together, Shope and Chapman modeled JPL's team approach to create effective instructional strategies that would:

- 1) Communicate the space science concepts called for by the tenth grade curriculum within a six-week time frame;
- 2) Give students a sense of the nature of science in the context of an authentic experience of how NASA/JPL conducts space exploration.

This resulted in the creation of the Space Exploration Team Inquiry model, a group science project instructional model that is of practical use to the high school science teacher and has broader implications in the teaching of the many disciplines of science and for the education of teachers of science.

University Preparatory Program

The Garfield High School students who participated in this action-based research belong to the University Preparatory Program (UPP) funded by NASA's Minority Initiatives efforts (Code EU), through California State University at Los Angeles. UPP targets motivated average to above-average Latino students interested in a pathway to a baccalaureate degree in the fields of mathematics and science. At Garfield High School, about eighty students per year enter the program at the ninth grade level and travel together as a cohort receiving integrated math and science instruction. The overall UPP goal is to provide support and encouragement to the participating students to apply successfully to enter the California State University system. UPP intervention includes meeting with science teachers, providing tutoring for students, and providing three experiences per year of visiting Cal State LA for a Saturday science workshop, but does not intervene directly into classroom practice.

NASA Education and Public Outreach

NASA's Office of Space Science (Code S) also funds science education development through the Education and Public Outreach programs of its flight projects, primarily in the form of creating curriculum support materials and conducting educator

workshops for teachers in science on current space science exploration efforts. These mission-based programs are mandated to reach underserved, underutilized—and underestimated—groups. At JPL, a multimission outreach testbed is used to research, develop, and implement effective programs. The effort is called VOICES, Validating Outreach Innovations for Community and Education Services, led by a consortium of Space and Earth Science missions, including the Outer Planets Program, Mars Program, Cassini, Galileo, Stardust, Deep Impact, Ulysses/Voyager, Earth Observing Missions, the Space Interferometry Mission (SIM), and the Deep Space Network. This instructional innovation was developed in the context of a VOICES program, *From the Outer Planets to the Inner City*, an urban education and public outreach initiative that explores ways to make a difference in inner city settings by engaging direct scientist, engineer, and science educator involvement, including direct intervention into formal classroom instruction and informal science learning opportunities.

The Space Exploration Experience at JPL

JPL is NASA's premier center for robotic space exploration missions. The selection of a mission begins as a dialogue between NASA and the space science research community. The science community recommends to NASA the scope of potential missions. NASA then offers competitive opportunities for participation in selected missions. Each mission consists of three fundamental components corresponding to the functions of science definition, flight project development, and communication of meaningful results. Each component's function is achieved by forming specific teams of experts.

The science definition team pulls together research scientists to focus and define the major science objectives of the mission. The flight project team brings together scientists, engineers, mission planners, and managers to solve the daunting technological problems that are associated with the construction of a sciencecraft and accomplishing the science objectives through data retrieval and analysis. The science education and outreach team communicates the nature of the mission and the knowledge gained through the mission to the education community and to the public at large. From the inception of the mission, all of these teams work together toward a successful completion of the mission.

Bringing the Space Exploration Experience to the Classroom

The classroom scientific inquiry structure was framed by the ED³U Teaching for Conceptual Change Model, a variation of the learning cycle developed by Dr. William McComas of the Center to Advance Science Education at the University of Southern California. ED³U refers to five phases in a learning cycle approach: explore a natural phenomenon, diagnose prior knowledge, design personally-relevant tests, discuss ideas and evidence-based results, and use newly constructed knowledge.

The following table lists each component of the ED³U teaching model and indicates the activities that we used to support each component:

Table 1

Space Exploration Team Learning Cycle Structure

ED³U= Explore + Diagnose + Design + Discuss + Use

Explore a natural phenomenon: Space Science Concepts

- Guided student exploration, utilizing NASA/JPL images, mission data, web sites; demonstration of key concepts; text resources and classroom discussion
- Using mime, students explore Solar Nebular Theory of Solar System Formation
- In teams, students select and study specific space science concepts related to group space science projects

Diagnose prior experience: Space Science Concepts

- Assess prior knowledge through Concept Map and MIME Activities
- Concept Map: used to gain insight to current level of student understanding
- Concept-embedded MIME Activities: The Planet You, Build a Living Spacecraft

Design a personally-relevant test: Core Science Learning Objectives

- Groups, as Science Definition Teams, negotiate definition of core science learning objectives, develop area of interest within realm of Space Science
- Groups, as Space Exploration Project Teams, relate technology component of project (spacecraft & subsystems) in order to craft strategies to develop a mission and achieve science learning objectives
- Groups, as Science Education and Outreach Teams, devise ways to organize and interpret results and present newly constructed knowledge, using visual, multimedia, oral, and mime techniques

Discuss ideas: Space Science and Technology

- Share research ideas and related technology issues in context of working as teams
- Work out details of group science project ideas
- Teachers and Students are co-learners in the retrieval and analysis of research data
- Mindful of curriculum objectives, as concepts emerge in process of team participation during class time, Teachers intervene, through mini-lectures, class discussions, and assigned work, to seize whole group learning opportunities

Use knowledge in practice: Communication of Space Science Concepts

- Devise preliminary and final presentations, with emphasis on use of mime and dramatization techniques to enhance conceptual clarity
- Use multiple pathways of communication

The table below defines the roles of the teams in each of the components of the Space Exploration Team Inquiry instructional model in relation to the NASA/JPL space exploration components:

Table 2

Bringing NASA/JPL to the Classroom: Space Exploration Team Inquiry Roles

NASA/JPL Components	Classroom Components
<p>Science Definition Team <i>Brings Scientists together in groups to:</i> 1. Reflect scientific curiosity negotiated in concert with science community. 2. Pose scientific questions that may contribute to new knowledge for science community and the general public; 3. Respond to space exploration priorities set by NASA that shape range of topics available for funding; 4. Define Core Science Objectives for NASA space exploration mission.</p>	<p>Science Definition Team <i>Brings Learners together in groups to:</i> 1. Reflect scientific curiosity negotiated in concert with teacher and team; 2. Pose scientific questions that may contribute to new knowledge for the class; 3. Respond to space exploration priorities set by curriculum that shape range of topics available for study, drawn from textbook, introductory activities (including MIME), classroom environment (posters, pictures, discussion, lectures), and the web; 4. Define Core Science Learning Objectives for space exploration project.</p>
<p>Space Flight Project Team <i>Brings together scientists, engineers, mission planners, and so on, to form a flight project team to:</i> 1. Research, design, and develop a mission that achieves core science objectives; 2. Design, construct, launch, navigate, and operate actual sciencecraft; 3. Retrieve, analyze, and interpret mission data, to construct explanatory generalizations and address scientific questions about space, leading to new cycles of scientific research.</p>	<p>Space Exploration Project Team <i>Brings Learners together to form a space exploration project team to:</i> 1. Research, design and construct a project that achieves the core science learning objectives; 2. Design, construct, launch, navigate, and operate actual space exploration project; 3. Retrieve and interpret information from existing resources, such as NASA/JPL data on web sites, contact with NASA experts, textbooks and class discussions, leading to new cycles of learning.</p>
<p>Science Education & Outreach Team <i>Brings together Scientists, Engineers, Science Educators to:</i> Communicate knowledge gained by the NASA space exploration mission in order to enable scientists, policy-makers, educators, students, and the general public to learn about and participate in space exploration.</p>	<p>Science Education & Outreach Team <i>Brings Learners together to:</i> Communicate knowledge gained by the Space Exploration Team to the whole class through written, oral, visual, multimedia, mime and dramatized forms of expression, in order to enable the other students to learn about and participate in space exploration.</p>

Research Design

The innovation did not seek to introduce ways *to add on* to an already overburdened curriculum, but *to replace* the six-week unit with a group science project that was modeled on how space science is conducted at JPL. We hypothesized that curriculum content knowledge would emerge through multiple pathways from the context of each inquiry phase. At the outset, the JPL Science Educator expressed a greater confidence in this hypothesis than the Science Teacher. In fact, while willing to take the risk, the Science Teacher was initially quite skeptical of the possibility of covering all the material called for by the curriculum.

Assumptions

We assumed that the NASA/JPL Space Exploration Team Inquiry model is an effective instructional approach in the high school classroom. Components of the model had been used in prior settings to instruct teachers of an inner city afterschool science program, to provide activity ideas for teachers attending JPL educator workshops, and for direct instruction of elementary, middle school, and high school students in a wide variety of settings. The Garfield experience was the first time the model had been used as the primary vehicle of instruction. The Science Teacher was able to reflect on the difference between his standard approach and the innovation because he was concurrently teaching another class covering the same subject matter without the innovation. The two groups were not, however, assumed to be equal, so the comparison was not structured to reflect a true experimental and control group.

Design Validity

The innovation was conducted as an action research process, with a class selected by convenience. The sample was small, functioning more like a case study. The innovation was accompanied by a variety of obstacles that required moment to moment adaptations. Some were typical of inner city settings such as a lack of internet access due to inadequate computer facilities, and trying to fit such a study into a busy JPL schedule, requiring flexibility on the part of the Science Teacher.

Variables

The Science Teacher devised a list of space science concepts that would be indicators of student success. We were interested in tracking student growth in attaining space science concepts. We assessed prior knowledge through use of a pre-test concept map. We assessed learning through video documentation of student projects and through a post-test that included an elaborated concept map, and three open questions:

What did you learn from your own group science project effort?

What did you learn from other students' group science presentations?

What did you learn from the book?

Based on these six strands of evidence we were able to form a picture of student progress related to the main components of the innovation.

Curriculum Content Objectives

Content emerged from the student group projects as they conducted research, asked questions, and presented ideas in class. The JPL Science Educator and the Science

Teacher often seized teaching opportunities to bring focused awareness to science content and nature of science issues. In the standard approach class, content was presented in sequence from the textbook through lectures, demonstrations, and activities led by the same Science Teacher.

Curriculum objectives and content were derived from the Science Links *Turn Left at Alpha Centauri* California State textbook, aligned with the National Science Education Standards. Space science and technology concepts included, but were not limited to, the structure of spacecraft, the role of science instruments, the formation of the solar system, star formation, comparative planetary structure and environments, the solar nebular theory, nuclear fusion, gravity, gravity assists, comets, solar wind, aurora phenomena, photon emission, spectral analysis, and black holes. Sociocultural concepts included how to work collaboratively, the necessity to solve obstacles such as assuring that each group had email access, and the change in the traditional teacher-student role, where the science educator and teacher became co-learners with the students.

Initial Challenge: Bridging the Prior Knowledge Gap

The Space Exploration Team Inquiry model is designed to help both teachers and students to understand the processes involved in space exploration. The initial challenge is to provide a common base of shared experience that resembles the kind of common base that NASA's expert groups walk into the room with.

An actual NASA/JPL science definition team is composed of principal investigators who are leaders in their fields, familiar with the nature of science and the demands of evidence-based research. Flight project teams consist of a group of expert

scientists and engineers who are already conversant with a broad range of technologies used in space exploration and are familiar with the leading edge of advanced technology development. Education and Public Outreach teams must stay current with space science, advanced technologies, and be conversant with issues in the education of teachers in science, who ultimately communicate this knowledge to students in the classroom.

For example, a recent Discovery Mission proposal called Venus Atmospheric Measurement Probe, proposed a crucial experiment: a sciencecraft would enter the thick, hot Venusian atmosphere to measure the proportions of rare, inert, or noble gases (Argon, Krypton, Neon, and so forth) in order to compare similar measurements taken on Earth, Mars, and at the Sun. To understand why such a mission represents a crucial experiment and in turn excites space scientists and engineers, one would need prior knowledge of the nature of science and of the solar nebular theory, which explains the formation of the Solar System.

To introduce Garfield students to the necessary prior knowledge, we prepared a kinesthetic mime activity. This activity engaged the students in acting out the solar nebular theory, a theory that explains how a supernova caused a cold and widely dispersed hydrogen gas cloud to collapse gravitationally to form a protosun, planets, and other objects—our Solar System. Thus in one 25-minute period we:

- 1) Introduced two nature of science concepts (the notion of a crucial experiment and the characteristics of a theory);
- 2) Created a common base of knowledge about the formation of the Solar System that would be applied throughout the unit; and

- 3) Engaged the students by getting them up out of their seats, moving around the room to float like a hydrogen gas cloud, then to explode like a supernova, to collide, and to obtain angular momentum—a novel approach that set the tone for using mime as a kinesthetic inquiry tool throughout the unit.

Through a series of similarly structured learning experiences, students developed a range of competencies, including comprehension of content, engagement in space science concepts, and willingness to be more expressive in discussion and project presentation. Each phase of inquiry engaged students in the content and placed emphasis on the nature of science, mediated by the presence of the JPL Science Educator and the Science Teacher. Students also learned to explore and to utilize NASA and JPL web resources, including how to contact JPL scientists, engineers, or science educators in the context of furthering their project. Moreover, students learned to utilize a variety of approaches in creative, cognitive, and communicative dimensions to express space science concepts.

Movement Integration Mirroring Experience: The MIME Approach

The MIME Approach, developed by Richard Shope, applies the art of mime as a cognitive tool, especially to bring attention to how mime integrates concepts through movement experiences. Mime fosters a shared experience in the process of exploring a natural phenomenon that is normally inaccessible, intangible, invisible, or otherwise abstracted from immediate experience. By devising movement integrations as apt analogies, such physicalized expressions give students direct and vivid impressions of the

content. Students are enabled to move toward an understanding of the actual phenomenon. The mimed actions engage the students in a context-rich experience that can translate into more conventional verbal and mathematical expressions of the conceptual content. For example, creating a mimed model of a gravity assist maneuver requires the cognitive and physical awareness of the concepts involved. With the mimed experience as a base of comprehensible input, math and higher-level thinking extensions became easier to introduce.

Following a mime activity, the teacher and students can refer to the shared experience as a common source upon which to draw. It becomes a common reference point of shared prior experience. Modifying and manipulating the mimed model can also effect conceptual change. The power of the dramatic presentation style of the MIME Approach helps make abstract space science and nature of science concepts become lively and tangible. The kinesthetic component (mime) motivates high interest in the science content and evokes expression of science concepts in a way that can be authentically assessed.

Our use of the MIME Approach:

- Evoked a shared base of experience around key space exploration concepts;
- Connected concepts and allowed students to organize those concepts;
- Created concrete perceptual experiences that led to abstract conceptual understanding--making concepts more concrete and connected to experience, as opposed to fact-based and unconnected;
- Engaged students in a nontraditional learning mode that provided novelty;

- Provided a bridge of comprehensible input to move students toward higher-level math and cognitive thinking about space science concepts.

Results

Curriculum Coverage was Comparable

The textbook for the unit (*Left Turn at Alpha Centuri*) contained 65 concepts/vocabulary. The students expressed 45 of these concepts/vocabulary on their final exam. This indicates that 70% of the intended concepts were actually covered. This was comparable to the coverage over the same period of time in another class taught only through a more standard textbook, lecture, and discussion approach.

Students Learned from Each Other

The following table lists concepts mentioned 4 or more times in part of the final exam. The number of students mentioning these concepts is indicated in the parentheses after each concept.

Table 3

Space Science Concepts Learned by Students

Own Group	Other Groups	From Book	From Concept Map
Gases and Dust (11)	Black Holes (14)	Gravity (5)	Black Holes (26)
Hydrogen is red (6)	Spiral into Black Hole (10)	Planets (5)	Nebulae (21)
Nebulae (6)	Survival Time in BH (7)	Rings of Planets (4)	Gravity (15)
Hydrogen and Helium (4)	Nitrogen Green Color (7)		Spectrum Analysis (11)
Planetary Nebulae (4)	Gases and Dust (6)		Star Formation (11)
Heat and Gas's glow (4)	Hydrogen Red Color (6)		Dust (9)
Black Holes (4)	Planetary Nebulae (6)		
	Cat's Eye Nebula (5)		

The Space Exploration Team Inquiry model demonstrated measurable student growth in content knowledge as well as enhanced affective attitudes toward science

learning. By analyzing the frequency of the mention of space science concepts and viewing videotaped student presentations, the data showed that twice as many concepts were conveyed in contexts where students were learning from each other than could be attributed to learning directly from the teacher or the book. The Space Exploration Team Inquiry model enabled much more frequent exchange among students.

Dramatic Altering of Teacher-Students Dynamic

The most dramatic results occurred in the arena of the complete altering of the group dynamics of the high school science classroom. While the JPL Science Educator and Science Teacher maintained their teacherly authority, they dropped their authoritative roles in the midst of the activities, and became immersed in interactions with the student Space Exploration Teams. Once motivated, the students are clearly placed in the driver's seat, demonstrating the confidence to inspire their own initiative and responsibility to complete their research and presentation tasks.

Here is one student's emailed thank-you note:

From: JR
Date: Sun, 25 Jun 2000 13:38:38 EDT
Subject: Thank you
To: Rick.shope@jpl.nasa.gov

Dear Mr. Shope,

I would like to thank you for making what I used to think was a boring science class into a fun one. I really felt like I was involved with the whole lesson and being involved helped me learn better and understand easier.

When you read something out of a book it gets boring and sometimes they use words you don't understand and you have to look up, so kind of side tracks you. It also made me feel like it wasn't just the teacher and the students but like we were all one whole. I really enjoyed you teaching our class and I really appreciate that you took time from your busy schedule to come teach us.

Sincerely, J R

Mime Enhanced the Learning Experience

The use of mime enhanced learning and generated an increased enthusiasm for science learning. The videotaped presentations demonstrated highly animated use of mime accompanied by explanation. It was through this medium that students reported learning concepts from each other. Mime became a true educational tool, accessed by students to model and communicate space science concepts.

Implications for the Education of Teachers in Science

This action research study demonstrated the fruitfulness of modeling high school educational strategies after real world space science inquiry. Adapting JPL's scientific inquiry approach to bringing robotic space exploration missions to fruition proved to be an effective model for a space science education module. The interdisciplinary nature of space exploration, including space science, physical science, astronomy, physics, chemistry, astrobiology, life sciences, Earth science, and others, lends itself well to inclusion into the school curriculum in a variety of ways.

The use of mime enhanced students' abilities to communicate their learning. This study clearly demonstrated that mime was an effective tool in the learning process as most students reported on all the presentations in the components of their final exams.

We think that the Space Exploration Team Inquiry model with the incorporation of the MIME Approach deserves further study within the science education community. Of particular interest is the role that the classroom teacher plays in this learning process. In our case, the Science Teacher and the JPL Science Educator contributed to each group

just like other student group members, by bringing relevant information that they knew or gained from research. This created a collaborative atmosphere in the classroom.

Thus, we plan to pursue more opportunities to create stronger studies that develop more data that will help us understand the breadth and depth of application of the two modalities, the Space Exploration Team Inquiry model and the MIME approach.

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Scientific and Science Education Background: Richard Shope has 30 years of experience as an educator, educational researcher, and leader in space science education and public outreach. He has extensive background in teaching, particularly for Gifted and Talented Education programs and English/Spanish Bilingual Education programs, as well as Science Education programs. For six years he has coordinated space science outreach programs for various flight projects at NASA's Jet Propulsion Laboratory. He conducts research in science education, writes articles, creates science learning activities, teaches teachers, and demonstrates innovative ways to bring the thrill of space science to people of all ages and cultural backgrounds. He earned his M.S.Ed in Science Education (1998) at the University of Southern California (USC) and is currently pursuing a Doctorate in Science Education, also USC.

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Representative Science Education and Public Outreach Research Papers:

The Space Exploration Team Inquiry Model: Linking NASA To Urban Education Initiatives in the High School Classroom (Paper presented at AETS conference, 2001)

Pluto: Ninth Planet of Not! Nine Lessons, Nine Models of Teaching! (JPL, 1999).

Margins of Error in Space Exploration and Intercultural Sensitivity: The NASA-Diné Consultations at Piñon (JPL, 1999).

Group Science Projects: An Assessment of Inner City Elementary Students (USC Masters Thesis, 1997)